THE ACOUSTIC POTENTIALS OF THE HUMAN AURICLE.

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AURAL SURGEON TO THE LONDON HOSPITAL, AND LECTURER ON DISEASES OF THE EAR TO THE MEDICAL SCHOOL.

Read before the Otological Section of International Medical Congress, 1881.

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ACOUSTIC POTENTIALS OF THE HUMAN AURICLE.

The Auricle not only forms a very important element as a feature in man and the lower animals, but subserves a variety of other purposes, such as the protection of the delicate organ which it surrounds, preventing sensible perspiration as it trickles over the head from entering the ear, protecting it from wind and weather, dust, and the rays of the sun, the impact of various substances incidental to active existence. The mobility of the Auricle causes cerumen which has served its purpose, to be dislodged and fall out instead of remaining to irritate and block the organ it is designed to protect. It also subserves the keeping-up of an equable temperature and a proper degree of natural moisture within the ear—too great a range in the variability of either of these conditions being extremely detrimental to the organ.

But the point to which I would now wish to direct attention is the functional relation of this important member to the deeper-seated parts concerned in hearing.

Authorities differ very much as regards the real acoustic value of the Auricle, some have denied its acoustic properties, whilst it has been variously estimated by others as a "sound conductor, sound-condenser, or as a resonator for higher tones."*

But there has been no attempt to establish this latter on a scientific basis so far as I am aware, except that Zaufal pointed out the fact that friction over the tragus produced in some perfect specimens of Auricle, the middle C, by reason of the vibrations excited in its cartilage.

* Urbantschitsch. Lehrbuch der Ohrenheilkunde, page 85.

The object of this paper is to give the results of some experiments which I have lately tried on the Auricles of musical persons. These results show not only that the pitch of the friction-sound on the tragus is as above-stated, but also that in a well-formed Auricle the whole free margin of the cartilage gives a beautifully graduated ascending scale of notes forming a complete octave from the tragus in front to the posterior border of the helix behind (C, D, E, F, G, a, b, c).

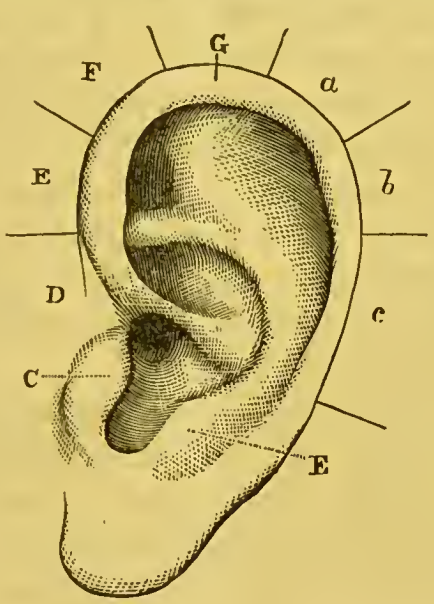

Fig. 1.

Fig. 1.—Diagram showing the musical notes proper to the parts of the Auricle marked off.

The antitragus forms a distinct and isolated note, the E, which serves to reinforce the E of the helix. The octave harmonic of the C is also reinforced by its octave c (fig. 1).

The notes or friction-sounds are produced by quickly passing the finger or the rubber-end of a pencil over the different segments between the radial lines indicated in fig. 1. The radial lines themselves indicate the positions of the semitones, or sharps and flats of the whole notes. I have not yet attempted to give the resonance value of the antihelix, but it no doubt aids somewhat in reinforcing the notes of the helix.

Now it is very remarkable that the notes forming the basis

of all music, viz., the *1st Major triad* or *Tonic* (C, E, G,) are very distinctly produced by friction on the tragus, antitragus, and middle of the upper border of the rim of the helix.

The cartilage of the rim of the helix in a well-formed ear diminishes gradually in width and frequently in thickness from before backwards, and the amount of hollow space formed by the various fossæ underlying each section of the rim, as marked off by the radial lines in fig. 1, diminishes in inverse proportion to the pitch of the note of the part it underlies. These two facts are quite in keeping with acoustic principles as illustrated in the construction of the resonance chambers of such musical instruments as the harp.

Upon careful examination of the *intrinsic** muscles of the pinna, we must be forced to the conclusion that they are serviceable chiefly in increasing the tension, and thus raising the pitch of the resonance of different parts of the cartilage and regulating the size of its fossæ.

The following simple experiment may serve to illustrate the first of these observations : Take an ordinary visiting card and bend up and over one of its long edges, about a quarter of an inch in width, without cracking the card ; this edge on being rubbed by passing a finger over it at right angles will produce a certain note ; now bend the card slightly in the opposite direction, and at right angles with the first bending, that is across its shorter diameter ; as you bend it more and more the friction-sound keeps rising until it has passed through a complete octave. This rise of pitch is due to increased tension of the edge of the card, and a tendency to form a more and more distinct nodal point at the intersection of the two bendings and nodal lines coinciding with these latter.

In a similar manner the action of the *intrinsic* muscles of

* It may be mentioned for the benefit of the general reader that the *extrinsic* muscles are those which determine the visible movements of the Auricle as a whole upon the surface of the skull, and the *intrinsic* muscles those which modify the contour of the Auricle itself, and bring about those changes which are the subject of this paper.

the Auricle is to increase the tension of the cartilage, and to establish more decided nodal points and lines upon its surface, thus raising the resonance pitch of the various parts; and bringing out more distinctly the higher harmonics or upper partials both of speech and music.

This will be now shown in detail.

ACOUSTIC VALUE OF THE ACTION OF THE INTRINSIC MUSCLES OF THE AURICLE.

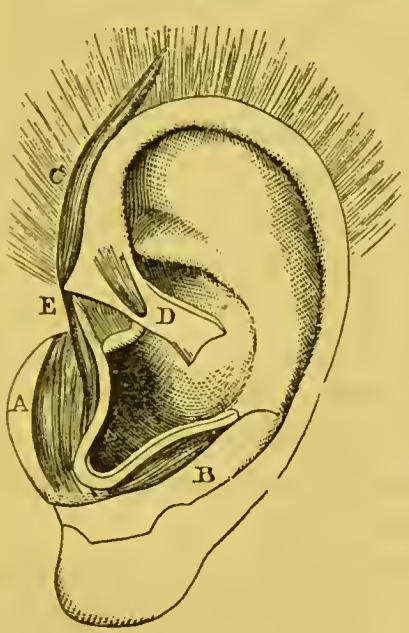

FIG. 2.

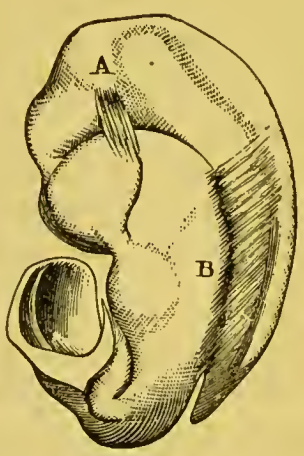

FIG. 3.

FIG. 2.—External surface of Auricle (partly dissected) showing (A) *Musculus Tragicus*, (E) its occasional prolongation to the spine of the helix, (B) *M. Antitragicus*, (C) *M. Helicis Major*, (D) *M. Helicis Minor—after* HENLE.

FIG. 3.—Posterior surface of the cartilage of the Auricle showing (A) *M. Obliquus Auriculæ*, (B) *M. Transversus Auriculæ—after* HENLE.

Musculus Tragicus: Raises the pitch of the note C, and when its fibres reach as far as the spine of the helix it probably heightens the note D above.

M. Antitragicus: Probably sharpens the antitragic note E.

M. Helicis Major } Sharpen the notes D, E, F, and G.
„ „ *Minor* }

M. Transversus Auriculæ: Probably sharpens the note G, but especially the notes a, b, c.

M. Obliquus Auriculæ: Sharpens the notes D and E.

The range of pitch which the *intrinsic* muscles of the ear have at their command is no doubt very considerable and perhaps may before long be determined by causing them to contract under electric stimulus. It will be noticed that I have in dwelling upon their individual actions, spoken reservedly on this point and only alluded to their power of sharpening the notes under their influence. But it is highly probable the real range of their power in this respect may reach at least from three to four complete tones, so that taking the tragus, antitragus, and the vertex of the helix of the cartilage in a state of rest at the vibrational (*v.s.*) values of 264, 330, and 396 Society of Arts pitch, that is having the ratios 4 : 5 : 6 and therefore capable of yielding the Tonic or *1st Major triad*, contractions of the muscles, indicated as affecting these portions of the cartilage, sufficient to raise the pitch by three notes, will produce the *3rd Major triad* or Sub-dominant, and if raised *four notes* will produce the *2nd Major triad* or Dominant, in each case maintaining the ratio 4 : 5 : 6.

The next figure gives, in a diagramatic form, the portions of the cartilage concerned in resonance with the three Major triads.

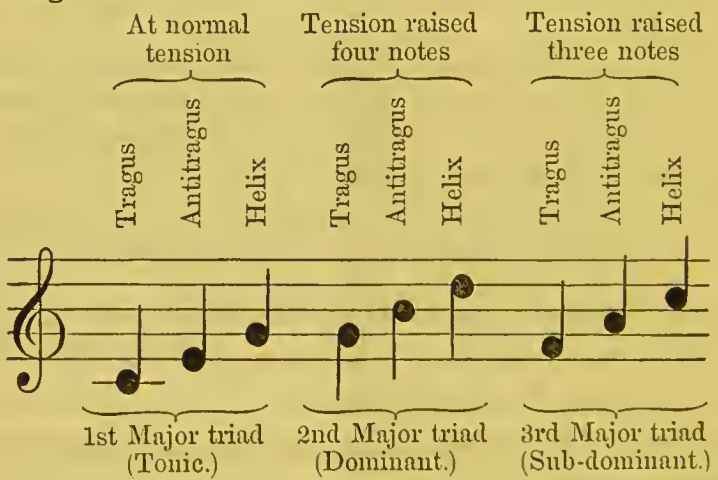

Fig. 4.

The value of the cartilage of the Auricle as a resonator of wide range (some three octaves at least) will be much more

apparent when we take into consideration that every well and distinctly sounded note has accompanying it harmonics extending over from two to three octaves, so that whilst a deep fundamental note may obtain *per se* no response from the cartilage, its higher partials are considerably reinforced.

The remaining notes of the octave on the pinna will, of course, enjoy the same range as the notes belonging to the special parts just mentioned.

It will be easily understood that the low pitch of the sound, considering the *smallness* of the parts involved, is due to two causes; first, the cartilage has neither the density nor the tension of substances used for the purposes of illustrating resonance in ordinary physical experiments on sound, and, secondly, it is considerably muffled by its tegumentary covering.

When the cartilage is stripped and dried the sounds elicited by friction are much higher in pitch, and very harsh and unpleasant in quality. If this condition were present in the living subject, higher notes would become intolerable to the ear. Probably, in advancing age, the increased density of the cartilage, and in many instances its thinner covering, particularly aids the hearing, by increasing the resonance, of higher tones, and thus somewhat compensates for the failing perception of these notes on the part of the cochlea.

The *extrinsic* muscles of the ear, those passing between the skull and the pinna, no doubt much assist in the transmission of the vibrations falling upon this part to the inner ear, by rendering its attachment to the head more tense during the act of listening and keeping the tubular part of the cartilage and its membranous connecting link well open; this also increases the resonance of the air in the external meatus. They are also most important in determining the direction of sound.

The External Ear then, or Auricle, is (a) in the first place protective; (b) it aids in catching by its increased area a larger amount of the sound waves falling on it and conducting them to the ear than would arrive there if it were absent; (c) it conducts part of these immediately to the temporal bone,

and so to the nerve of hearing, and part by its ordinary funnel action ; (d) it gives knowledge of direction* of sound, especially when acting with its fellow of the opposite side ; and (e) by its resonant qualities it reinforces musical sounds in the manner and by the means already set forth, and so aids in no uncertain way the perception of musical sounds reaching the ear by intensifying the higher notes and the higher harmonics, or upper partials, of the lower notes of the musical scale.

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* The *perception of direction* of impressions is a faculty common to all our senses, and is brought about by analogous means in every case. Even in the vegetable world the *perception of direction* is very remarkable, whether it be the permanent turning of leaf and flower towards a window, or these same following the daily course of the sun through the heavens, the scent of the *radical* for water and *humus*, or of the *plumule* for light and air.

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